Mon. Not. R. Astron. Soc. **000**, 1–5 (2003) Printed 2 February 2008 (MN LaTeX style file v2.2)

Chandra observations of five X-ray transient galactic nuclei

S. Vaughan,[1,2] R. Edelson[3] and R. S. Warwick[2]
[1] *Institute of Astronomy; Madingley Road; Cambridge, CB3 0HA*
[2] *X-Ray Astronomy Group; University of Leicester; Leicester, LE1 7RH*
[3] *Astronomy Department; University of California; Los Angeles, CA 90095-1562; USA*

Accepted: 14/1/2004; Submitted: 23/12/2003; in original form: 12/11/2003

ABSTRACT

We report on exploratory *Chandra* observations of five galactic nuclei that were found to be X-ray bright during the *ROSAT* all-sky survey (with $L_{\rm X} \gtrsim 10^{43}$ erg s^{-1}) but subsequently exhibited a dramatic decline in X-ray luminosity. Very little is known about the post-outburst X-ray properties of these enigmatic sources. In all five cases *Chandra* detects an X-ray source positionally coincident with the nucleus of the host galaxy. The spectrum of the brightest source (IC 3599) appears consistent with a steep power-law ($\Gamma \sim 3.6$). The other sources have too few counts to extract individual, well-determined spectra, but their X-ray spectra appear flatter ($\Gamma \sim 2$) on average. The *Chandra* fluxes are $\sim 10^2 - 10^3$ fainter than was observed during the outburst (up to 12 years previously). That all post-outburst X-ray observations showed similarly low X-ray luminosities is consistent with these sources having 'switched' to a persistent low-luminosity state. Unfortunately the relative dearth of long-term monitoring and other data mean that the physical mechanism responsible for this spectacular behaviour is still highly unconstrained.

Key words: galaxies: active – galaxies: nuclei – galaxies: Seyfert – X-rays: galaxies

1 INTRODUCTION

Very large amplitude variations in the X-ray luminosity (greater than a factor $\gtrsim 100$) emanating from galactic nuclei are unquestionably an indicator of unusual and interesting phenomena. Such 'transient-like' behaviour has been observed in only a handful of galaxies to date (see Donley et al. 2002 and Komossa 2002) through observations with *ROSAT*[1]. These soft X-ray bright galactic nuclei detected during the *ROSAT* all-sky survey (RASS) were found in subsequent follow-up observations with the same satellite to be fainter, by factors of $70 - 400$, than their initial RASS detection. Such spectacular long-term fading is markedly different from the persistent variability usually exhibited by soft X-ray bright Active Galactic Nuclei (AGN).

One possible explanation is that these sources are intrinsically quiescent objects (dormant or inactive galactic nuclei) that were subject to a luminous outburst near the time of RASS, followed by a decline in luminosity over timescales of months or years. This scenario is explained by the tidal disruption model in which the X-ray outburst is the result of a supermassive black hole in the nucleus of a inactive galaxy capturing and accreting a passing star (e.g. Gurzadian & Ozernoi 1980; Rees 1988). Alternatively, a very different type of model is that in which an otherwise normal (i.e. X-ray luminous) AGN suddenly 'switches off,' possibly as the result of the thermal-viscous accretion disk instabilities known to operate in Galactic accreting sources (Siemiginowska et al. 1996). See Komossa (2002) and references therein for further discussion of these and other models.

This letter presents exploratory *Chandra* observations of five of the best-studied X-ray transient galactic nuclei. The sample comprises WPVS 007, IC 3599, RX J1242.6-1119, NGC 5905 and RX J1624.9+7554. Very little is known about the post-outburst X-ray properties of these sources and these new observations almost double the total number of post-RASS detections for this sample. The rest of this letter is organised as follows. Section 2 describes the *Chandra* observations and X-ray data analysis. Section 3 discusses the optical source classification and the construction of X-ray light curves by combining these new *Chandra* data with earlier measurements. Finally, section 4 discusses the implications of these results. Throughout this letter the cosmological parameters are assumed to be $H_0 = 70 \ {\rm km\,s^{-1}} \ {\rm Mpc^{-1}}$ and $q_0 = 0.5$.

2 OBSERVATIONS AND DATA ANALYSIS

2.1 Observations

The five targets were each observed close to the aim-point of the back-illuminated ACIS chip S3 (ACIS-S3). As the expected X-ray fluxes for these objects were uncertain by an order of magnitude, four of the observations were performed with the ACIS CCDs using the quarter-frame subarray. This reduced the CCD readout time

[1] Piro et al. 1988 reported a factor of $\gtrsim 20$ decrease in the $0.5 - 4.5$ keV luminosity of E1615+061 between *HEAO-1* A2 and *Einstein* observations; however, *ASCA* measured rapid, persistent variability in this object (Guainazzi et al. 1998) suggesting that it does not fit the above definition.

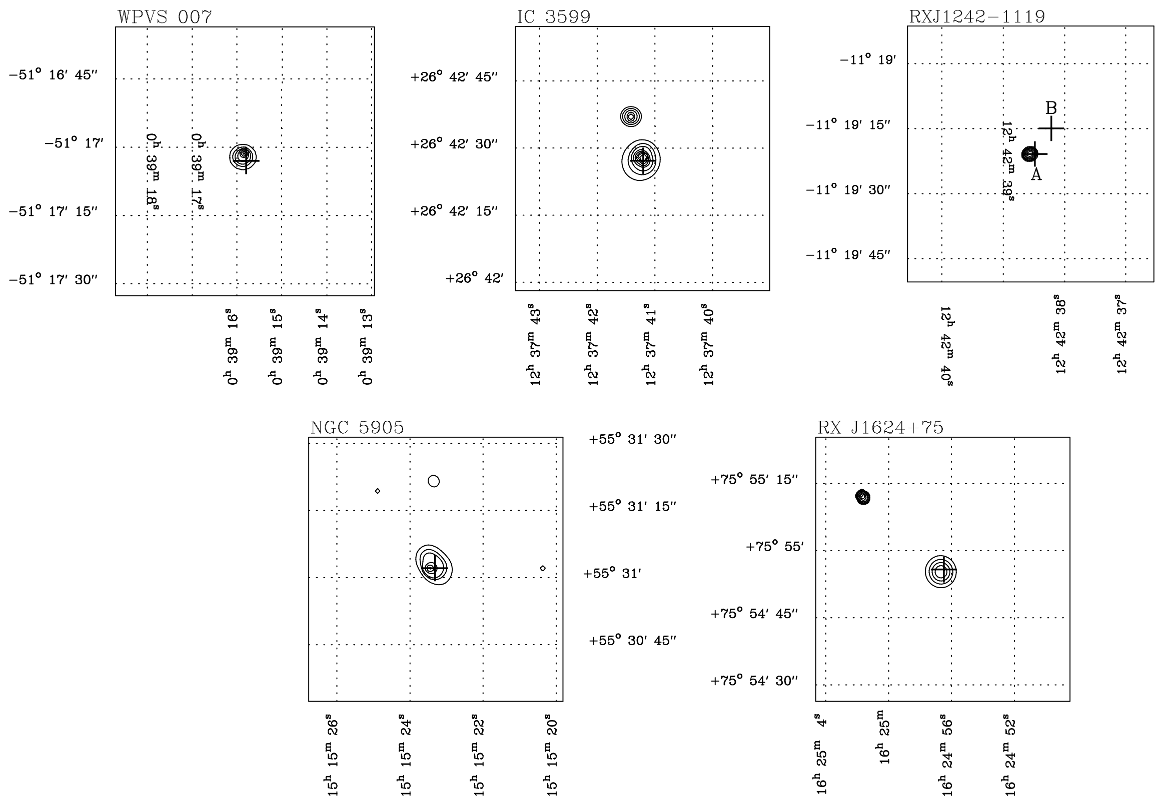

Figure 1. Contour plots of the X-ray intensity derived from full-band ($0.3 - 7.0$ keV) ACIS-S3 images of the five target sources. Each image spans $60'' \times 60''$ and has been adaptively smoothed at the 2σ level (Ebeling, White & Rangarajan 2003). Crosses mark the optical positions of the galactic nuclei. The nucleus of each member of the galaxy pair is indicated in the case of RX J1242.6-1119.

(to 1.07 s) and thereby reduced any possible effects from photon pile-up (Ballet 1999) if the sources were brighter than expected. The observation of RX J1242.6-1119 was performed in full-frame mode.

The data were processed from the level-1 events files using `CIAO v2.3`. Only events corresponding to grades 0, 2, 3, 4 and 6 were used in the analysis of processed data. Flares in the background level were identified by examining the light curve from the whole ACIS-S1 chip. These showed that the observations of WPVS 007, IC 3599 and RX J1242.6-1119 were free from background flares. The observation of RX J1624.9+7554 showed an increase in the background level in the final ~ 200 s of the observation; data taken during this time interval were removed prior to analysis. The observation of NGC 5905 suffered from a higher background level (compared to the other observations) such that the removal of the periods of high background would leave insufficient data for analysis. Therefore, the full exposure of NGC 5905 was analysed accepting that the background level was enhanced. Table 1 lists the basic properties of the five target sources and their *Chandra* observations.

2.2 X-ray Imaging

Figure 1 shows the X-ray contour plots derived from the ACIS images for the five targets after adaptive smoothing has been applied. Clearly in all cases there is an excess of photons coincident with the optical position of the galactic nucleus (i.e. within the expected $\sim 2''$ uncertainty in the optical position). The optical positions were taken from the references given in Section 3 and the NASA/IPAC Extragalactic Database[2] (NED).

In the case of RX J1242.6-1119 the positional error circle of the RASS X-ray source contains a pair of inactive galaxies, labelled A and B by Komossa & Greiner (1999). From the *ROSAT* data it was not clear which of the two galaxies should be identified with the X-ray source. The X-ray source detected by the *Chandra* observation is clearly coincident with galaxy A (Fig. 1). Assuming that this is the same X-ray source as detected by *ROSAT* then the X-ray outburst should be associated with galaxy A. All the X-ray sources appear consistent with being point-like with the possible exception of NGC 5905, which displays a slightly asymmetric shape in the smoothed image. However, with only ~ 25 counts in the source and an enhanced background level it is difficult to be more confident of this without a more sensitive observation. It is interesting to note that of the five targets NGC 5905 is the nearest ($1''$or 2 pixels corresponds to a spatial scale of ~ 0.2 kpc at the source redshift) and thus might be most likely to show extended emission in the *Chandra* images.

2.3 Count Rates and Softness Ratios

Source counts were estimated by performing photometry on the raw (unsmoothed) images with a circular aperture of radius of $2''$centred on the source. The background level was estimated from a concentric annulus with inner and outer radii of $3''$ and $60''$, respectively (excluding nearby sources where present). The net

[2] `http://nedwww.ipac.caltech.edu/`

Table 1. Source observation log and properties.

Source Name	R.A. (J2000)	Dec (J2000)	z	$N_{\rm H}$ [a] (10^{20} cm^{-2})	Observation Date	Exposure (ks)	Counts[b]	SR[c]	Flux[d]	$L_{\rm X}$ [e]
WPVS 007	00 39 15.8	-51 17 03	0.029	2.6	2002 Aug 2	9.3	9.8 ± 4.2	2.4 ± 1.7	0.89	2×10^{40}
IC 3599	12 37 41.2	26 42 29	0.022	1.3	2002 Mar 7	10.2	247.8 ± 16.8	5.2 ± 0.9	17	2×10^{41}
RX J1242.6-1119[f]	12 42 38.5	-11 19 21	0.05	3.6	2001 Mar 9	4.5	17.9 ± 5.3	1.3 ± 0.6	2.8	2×10^{41}
NGC 5905	15 15 23.4	55 30 57	0.011	1.4	2002 Oct 4	9.6	25.3 ± 6.6	1.3 ± 0.6	1.8	6×10^{39}
RX J1624.9+7554	16 24 56.5	75 54 56	0.064	3.8	2002 Sep 15	10.1	3.5 ± 3.2	0.3 ± 0.4	0.24	3×10^{40}

[a] Galactic column density from Dickey & Lockman (1990). [b] Larger of the two 1σ error bounds using the approximation of Gehrels (1986). [c] SR is the $0.3-1.0/1-7$ keV softness ratio. [d] Flux in the $0.3-7.0$ keV band (10^{-14} erg s^{-1} cm^{-2}). [e] The estimated unabsorbed X-ay luminosity in the same band (erg s^{-1}). [f] Optical position of galaxy A (Komossa & Greiner 1999).

counts associated with each source are given in Table 1. The brightest object, IC 3599, has $\gtrsim 200$ photons in its X-ray image, enough for crude spectral analysis (see below). The other four detections are based on far fewer counts. In the case of RX J1624.9+7554 there are only 4 counts in the source aperture, i.e. a $\sim 2\sigma$ confidence detection (with negligible background), but the coincidence with the optical position makes this a likely detection of the nuclear X-ray emission.

Softness ratios were calculated for use as a crude indicator of the spectral slopes of the faint sources. The softness ratio was defined as the ratio of counts in the bands $0.3-1.0/1.0-7.0$ keV. These are given in Table 1 and show IC 3599 to have a very soft spectrum with the other four sources showing somewhat harder emission. For the three harder sources (RX J1242.6-1119, NGC 5905 and RX J1624.9+7554) the softness ratio corresponds to a power-law photon index $\Gamma \leqslant 2.5$. The measured softness ratio of IC 3599 requires $\Gamma \sim 4$ (see below).

In all cases the $0.3-7.0$ keV flux was estimated using the `PIMMS` calculator at the *Chandra* X-ray Center[3]. For this purpose the spectrum was assumed to be a power-law (with a photon index $\Gamma = 3$) modified by Galactic absorption. The estimated fluxes are listed in Table 1. If the underlying X-ray spectra differ substantially from the assumed spectral form then these flux estimates may change by a factor of a few. The $0.3-7.0$ keV unabsorbed luminosities were estimated assuming the same spectral model and are also listed in the table.

2.4 X-ray Spectrum of IC 3599

Spectra were extracted from the source and background regions of the observation of IC 3599. A response matrix and an ancillary response file were generated with `mkrmf` and `mkwarf`, respectively. The low number of counts meant that applying standard binning (i.e. $N \geqslant 20$ counts per energy bin) would result in too few bins for spectral fitting. Therefore the unbinned spectrum was fitted by minimising the C-statistic (Cash 1979), appropriate for situations when spectra contain few counts. The fitting was performed in `XSPEC v11.2` (Arnaud 1996).

The spectral fitting was restricted to the $0.6-7.0$ keV band since the ACIS calibration is uncertain below 0.6 keV. A power-law model with Galactic absorption gave a best-fitting photon index of $\Gamma = 3.56^{+0.37}_{-0.34}$ (90 per cent confidence limits) which is steeper than that normally seen in Seyfert galaxies. This fit is shown in Figure 2. Fitting with alternative spectral models (blackbody or

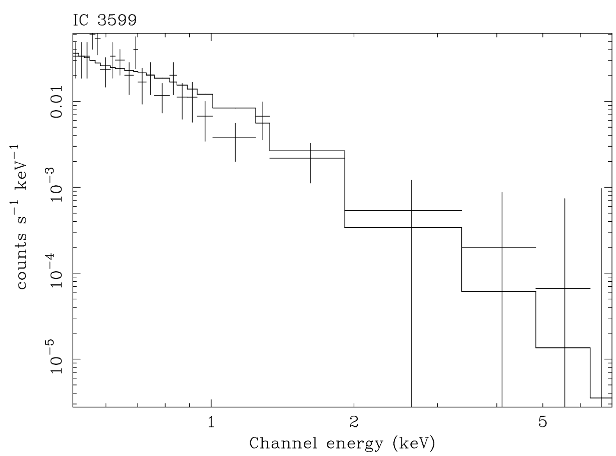

Figure 2. ACIS-S3 spectrum of IC 3599 (crosses) fitted with a power-law model (histogram). The data have been rebinned for display purposes.

bremsstrahlung continuum or a `mekal` plasma model) gave noticeably larger data/model residuals. The best-fitting temperatures were $kT \sim 0.16$ keV for a blackbody and ~ 0.26 keV for a `mekal` plasma model.

3 COMPARISON WITH OTHER OBSERVATIONS

3.1 X-Ray light curves and softness ratios

In order to better understand how these sources have changed since their X-ray outbursts, long term light curves were constructed for each of the five sources, as shown in Fig. 3. For this purpose the *Chandra* $0.3-7.0$ keV count rates were converted into $0.3-2.0$ keV fluxes using `PIMMS`, assuming the energy spectrum is a steep power-law (with $\Gamma = 3$) modified by Galactic absorption. The $0.3-2.0$ keV band was chosen as both the *Chandra* ACIS and *ROSAT* PSPC cover this energy range with reasonable effective area. The *ROSAT* data points were derived from both the RASS and pointed observations of each source (see below for references). The $0.1-2.4$ keV PSPC count rates were converted to $0.3-2.0$ keV fluxes assuming the same spectrum as above. In addition a single *ROSAT* HRI observation of NGC 5905, taken in 1996 October, is included. Since the largest uncertainty associated with these flux estimates is due to the model-dependence of the counts-to-flux conversion the fluxes were also calculated assuming $\Gamma = 2$ and $\Gamma = 4$. This resulted in flux estimates differing by factors $\gtrsim 2$ from the fiducial model and the error bars shown in Fig. 3 reflect this large uncertainty.

[3] `http://asc.harvard.edu/`

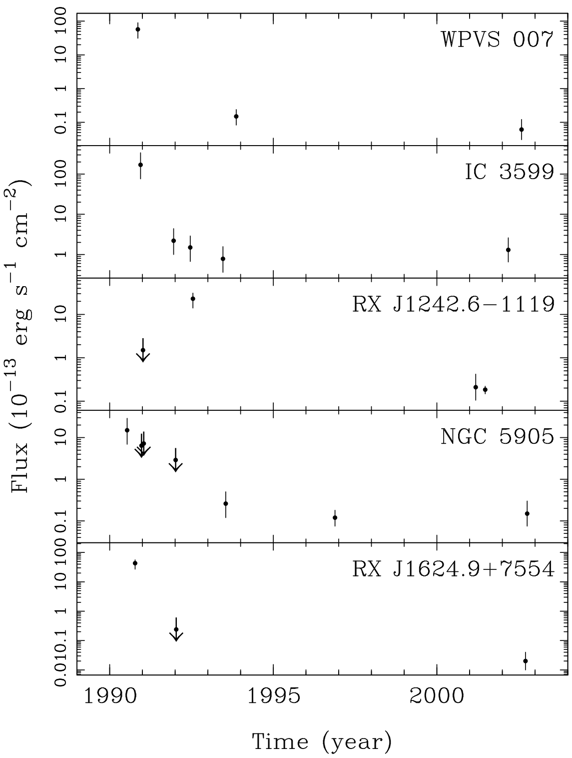

Figure 3. Historical light curves of soft X-ray ($0.3-2.0$ keV) flux compiled from *ROSAT* PSPC observations (left hand side flux points) and new *Chandra* observations (data points on far right). In addition, the fluxes derived from one *ROSAT* HRI observation of NGC 5905 (1996.9) and one *XMM-Newton* observation of RX J1242.6-1119 (2001.5) are also shown. Upper limits on the flux, derived from non-detections with *ROSAT* are marked with arrows.

XMM-Newton observed RX J1242.6-1119 during 2001 June 21-22, for a duration of 30.1 ks, and detected the X-ray source (with $\approx$ 286 counts). A spectrum was extracted from the EPIC pn data (using standard procedures) and fitted in XSPEC. This was well-fitted with a simple absorbed power-law model ($\Gamma = 2.42 \pm 0.23$, consistent with the estimates from section 2.3). The $0.3 - 2.0$ keV X-ray flux was well-constrained at $\approx 1.8 \times 10^{-14}$ erg s^{-1} cm^{-2}, consistent with the *Chandra* measurement. This flux point is also shown in Fig. 3.

As can be seen, for all five sources the *Chandra* fluxes lie at least two orders of magnitude below the brightest measured *ROSAT* fluxes. None have shown a significant increase in flux at any time during the (albeit poorly-sampled) period since the huge decline in flux was first established. These results are all consistent with a decline from high luminosity to a persistent low luminosity ($L_{\rm X} \sim 10^{40} - 10^{41}$ erg s^{-1}) over a timescale $\lesssim 2$ years.

The *Chandra* softness ratios also indicate changes. For all five objects the *ROSAT* X-ray spectrum was extremely soft during outburst. In fact WPVS 007 was the softest spectrum AGN observed during the RASS (Grupe et al. 1995b) with an effective photon index $\Gamma \sim 8$. The other objects showed slopes in the range $\Gamma = 3-5$ (Brandt, Pounds & Fink 1995; Komossa & Greiner 1999; Grupe, Thomas & Leighly 1999; Bade, Komossa & Dahlem 1996). In the case of IC 3599 the spectrum remains rather soft. For the other four objects the *Chandra* softness ratios suggest harder spectra ($\Gamma \lesssim 2.5$). However, it is difficult to make a more quantitative comparison due to the different energy ranges of the *ROSAT* and *Chandra*/ACIS spectra and the small number of source photons in the *Chandra* data.

3.2 Optical Spectra and Classification

WPVS 007: Two years prior to its RASS detection an optical spectrum was obtained by Winkler, Stirpe & Sekiguchi (1992). They classified the source (#7 in their notation) as a Seyfert 1. Observations by Grupe et al. (1995b) taken two years after the RASS detection identified WPVS 007 as a Narrow-line Seyfert 1 galaxy (NLS1; Boller, Brandt & Fink 1996). An *HST*/FOS ultraviolet spectrum taken in 1996 also showed broad permitted lines as well as intrinsic, ionised absorption (Crenshaw et al. 1999; Goodrich 2000).
IC 3599: The optical spectrum taken five months after its initial RASS detection showed IC 3599 to be a NLS1 (Brandt et al. 1995). However, further observations 14 months after the RASS detection showed the optical spectrum to have changed to resemble that of a Seyfert 1.9 (Grupe et al. 1995a). Observations in subsequent years confirmed this (Grupe et al. 1995a; Komossa & Bade 1999).
NGC 5905: This source was identified as an H II/starburst galaxy six years after its RASS detection (Bade, Komossa & Dahlem 1996; Komossa & Bade 1999). However, higher spatial resolution spectroscopy with *HST* revealed narrow, high-ionisation lines originating from the nucleus (Gezari et al. 2003). These imply the presence of a low-luminosity Seyfert 2 nucleus that was swamped by the surrounding H II emission in the previous observations. Gezari et al. (2003) used the correlation between Hα and soft X-ray luminosity described by Halderson et al. (2001) to estimate the soft X-ray luminosity of the nucleus to be $L_{0.1-2.4} \sim 4 \times 10^{40}$ erg s^{-1}, a factor $\lesssim 6$ larger than the X-ray luminosity actually observed by *Chandra*.
RX J1242.6-1119 and RX J1624.9+7554: These appeared as otherwise inactive galaxies when observed several years after their initial *ROSAT* detections (Komossa & Greiner 1999; Grupe, Thomas & Leighly 1999). Gezari et al. (2003) report no detectable non-stellar continuum or high-ionisation line emission in their *HST* observations.

4 DISCUSSION

As is clear from the light curves, in all five cases the flux recorded by *Chandra* falls $2 - 3$ orders of magnitude below the maximum flux observed by *ROSAT*. Although the light curves are sparsely sampled this does strongly suggest that the X-ray light curves are best characterised by a single, dramatic decline in luminosity on a timescale of $\lesssim 2$ years followed by a period of relative quiescence. This is consistent with the X-ray outbursts being non-recurring events (at least on timescales $\lesssim$ 10 years). In the most extreme example, RX J1624.9+7554 faded by a factor $\gtrsim 1000$ between its RASS observation in 1990 October and its *Chandra* observation in 2002 September. The optical spectra seem to indicate a wide variety of source types, ranging from genuine AGN to inactive galaxies.

It is difficult to make a simple comparison with the fading predicted in the tidal disruption scenario (Rees 1988): $L_{\rm X} \propto (t - t_0)^{-5/3}$ (where t_0 is the time of the outburst event). The *Chandra* X-ray luminosities could contain a significant contribution from unrelated galactic emission such as star forming regions, bright X-ray binaries, diffuse emission components, etc. Indeed, individual Ultra-Luminous X-ray (ULX) sources in nearby galaxies can reach X-ray luminosities $\sim 10^{40}$ erg s^{-1} (Fabbiano & White 2003). This 'background' emission is an unknown quantity and, if

dominated by a few bright X-ray binaries, could also be variable. Thus the X-ray light curve following stellar disruption should be: $L_{\rm X} \sim N(t-t_x)^{-5/3}+C$ where C is the unknown background galactic emission. The model therefore has three unknowns (N, $t_{\rm x}$ and C) but the light curves unfortunately have only $2-5$ data points making the test rather meaningless. In the best sampled light curves (IC 3599 and NGC 5905) the last *ROSAT* flux is comparable to the *Chandra* flux, implying no further fading has occurred on a timescale of ~ 10 years. Unfortunately, in all five cases, it is not clear whether the quiescent source is a residual low-luminosity nuclear source or unrelated, background galactic emission.

The question of whether the 'switch off' marked the end of a single, isolated accretion episode (such as a tidal disruption event) or a rapid decrease in the luminosity of a persistent AGN (Seyfert galaxy to LLAGN) remains largely open. The peak luminosities were $L_{\rm X} \gtrsim 10^{43}$ erg s^{-1}, comparable with bright Seyfert 1 galaxies, while the quiescent luminosities are only $L_{\rm X} \sim 10^{40}-10^{41}$ erg s^{-1}. The latter are rather high compared to the nuclear emission expected from normal/inactive or starburst galaxies (see Fabbiano 1989) but quite comparable to those of low-luminosity AGN (LLAGN: Ptak et al. 1999; Roberts & Warwick 2000; Ho et al. 2001; Ptak 2001). Thus the evidence does favour the presence of LLAGN in these galaxies. The existence of long-lasting, high-ionisation optical line emission from the nuclei of WPVS 007, IC 3599 and NGC 5905 further suggests these may harbour some kind of long-lived AGN. However, it is difficult to make any strong claims about their prior X-ray activity since no suitable observations exist.

The remaining two galaxies, RX J1242.6-1119 and RX J1624.9+7554, show no evidence for a luminous AGN in their optical spectra and remain the best candidates for tidal disruption events, athough their (relatively) high residual X-ray luminosity may indicate some residual nuclear activity (as argued above). The optically inactive galaxy RX J1242.6-1119 is particularly interesting as this was the only one of the target sources to have been observed (although not detected) just prior to its outburst detection (see Komossa & Greiner 1999). This suggests a rise time for the outburst of less than two years.

Transient galactic nuclei represent a relatively new and exciting avenue of X-ray astronomy research (see Komossa 2002 for a review). So little is known about these objects that any future X-ray observations are potentially of great importance. For example, a longer observation of NGC 5905 could reveal whether the X-ray emission is extended (and hence due to the circumnuclear starburst, not a LLAGN). Deeper observations of IC 3599 would better define the X-ray spectrum and thereby help clarify the origin of the remaining low-luminosity X-ray emission. Future monitoring of these sources is needed to see whether they are persistently variable (which would imply on-going accretion) and, in particular, to see whether any show repeat outbursts. A severe hindrance to such a project is the dearth of known sources. Future large-area monitoring missions such as *Lobster* (Fraser 2002) are well suited to finding transient galactic nuclei and providing the most likely route to a reasonably sized sample of such objects (see discussions in Sembay & West 1993 and Donley et al. 2002) on which a concerted programme of follow-up observations might be based.

ACKNOWLEDGEMENTS

We thank Steve Allen for help with `CIAO`, Tim Roberts for useful discussions and an anonymous referee for a helpful report. SV acknowledges financial support from PPARC. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

REFERENCES

Arnaud K., 1996, in Jacoby G., Barnes J., eds, *Astronomical Data Analysis Software and Systems*, ASP Conf. Series Vol. 101, p17
Bade N., Komossa S. & Dahlem M., 1996, A&A 309, L35
Ballet J., 1999, A&AS, 135, 371
Boller Th., Brandt W. N., Fink H,. 1996, A&A, 305, 53
Brandt W. N., Pounds K. A., Fink H., 1995, MNRAS, 273, L47
Burderi L., King A. R., Szuszkiewicz E. 1998, ApJ, 509, 85
Cash W., 1979, ApJ, 288, 939
Crenshaw D. M., Kraemer S. B., Boggess A., Maran S. P., Mushotzky R. F., Wu C.-C., 1999, ApJ, 516, 750
Dickey J. M., Lockman F. J., 1990, ARA&A, 28, 215
Donley J. L., Brandt W. N., Eracleous M., Boller Th., 2002, AJ, 124, 1308
Ebeling H., White D. A., Rangarajan F. V. N., 2003, MNRAS, submitted
Edelson R., Vaughan S., Warwick R., Puchnarewicz E., George I. M., 1999, MNRAS, 307, 91
Fabbiano G., 1989, ARA&A, 27, 87
Fabbiano G., White N. E., 2003, in Lewin W., van der Klis M. eds., *"Compact Stellar X-ray Sources"*, Cambridge University Press, in press (astro-ph/0307077)
Fraser G. W., et al. , 2002, Proc. SPIE, 4497, 115
Gehrels N., 1986, ApJ, 303, 336
Gezari S., Halpern J. P., Komossa S., Grupe D., Leighly K. M., 2003, ApJ, 592, 42
Goodrich R. W., 2000, NewAR, 44, 519
Grupe D., Beuermann K., Mannheim K., Bade N., Thomas H.-C., de Martino D., Schwope A., 1995a, A&A, 299, L5
Grupe D., Beuermann K., Mannheim K., Thomas H.-C., Fink H. H., de Martino D., 1995b, A&A, 300, L21
Grupe D., Thomas H.-C., Leighly K. M., 1999, A&A, 350, L31
Grupe D. et al. , 1999, A&A, 350, 805
Guainazzi M., et al. 1998, A&A, 339, 337
Gurzadian V. G., Ozernoi L. M., 1980, A&A, 86, 315
Halderson E. L., Moran E. C., Filippenko A. V., Ho L. C., 2001, AJ, 122, 637
Ho L., et al. , 2001, ApJ, 549, L51
Honma F., Matsumoto R., Kat, S., 1991, PASJ, 43, 147
Komossa S., Bade N., 1999, A&A, 343, 775
Komossa S., 2002, Reviews in Modern Astronomy, 15, 27 (astro-ph/0209007)
Magorrian J. et al. , 1998, AJ, 115, 2285
Piro L. et al. 1988, ApJ, 325, L25
Ptak A., Serlemitsos P., Yaqoob T., Mushotzky R., 1999, ApJS, 120, 179
Ptak A., 2001, in White N. E., Malaguti G., Palumbo G. G. C., eds, *X-ray astronomy : stellar endpoints, AGN, and the diffuse X-ray background*, AIP conference proceedings Vol. 599, p326 (astro-ph/0008459)
Rees M. J., 1988, Nature, 333, 523
Roberts T. R., Warwick R. S., 2000, MNRAS, 315, 98
Sembay S., West R. G., 1993, MNRAS, 262, 141
Siemiginowska A., Czerny B., Kostyunin V., 1996, ApJ, 458, 491
Terashima Y., Iyomoto N., Ho L. C., Ptak A. F., 2002, ApJS, 139, 1
Winkler H., Stirpe G. M., Sekiguchi K., 1992, A&AS, 94, 103

This paper has been typeset from a TEX/ LATEX file prepared by the author.